CLAIMS

I/WE CLAIM:

1. A method of adjusting the performance of a model-free adaptive controller having a delay predictor, comprising the steps of:

a) establishing a selectable performance index Ip ranging from substantially 0.01 to substantially 100;

b) setting the controller gain as Kc = Ip/K, where Kc is the controller gain, K is the estimated process static gain, and Ip is the selected performance index; and

c) setting the controller time constant as Tc = T/Ip, where Tc is the controller time constant, T is the estimated time constant of said delay predictor, and Ip is the selected performance index.

2. A model-free adaptive quality variable control system, comprising:

a) a model-free adaptive controller having an error input and a control output;

b) a controlled process having a control input and a process output, and having a delay time process and a feedforward process associated therewith, the input of said feedforward process being a disturbance, and the output of said delay time process being the process variable;

c) a feedforward controller having said disturbance as an input and having a feedforward controller output;

d) a delay predictor having as its inputs said control output and said process variable, and having as its output a dynamic feedback signal; and

e) a setpoint signal;

f) said error signal being the difference value of said setpoint signal and said dynamic feedback signal;

g) said control input of said controlled process being the sum of said control output and said feedforward controller output; and

h) the input of said delay time process being the sum of said process output and the output of said feedforward process.

3. The control system of Claim 2, in which said feedforward controller has the Laplace transfer function of

$$G_{fc}(S) = \frac{K_{fc} e^{-\tau_{fc} S}}{T_{fc} S + 1},$$

wherein $G_{fc}(S)$ is the Laplace transfer function of the feedforward controller; K_{fc} is the gain of the feedforward controller; T_{fc} is the feedforward time constant; τ_{fc} is the feedforward delay time; and S is the Laplace operator.

4. The control system of Claim 2, in which the delay time of said delay time process is much larger than the delays inherent in said controlled process and said feedforward process, and the gain of said feedforward controller is set at

$$K_{fc} = -\frac{K_f}{K_p},$$

wherein K_{fc} is the forward controller gain; K_f is the estimated static gain of said feedforward process; and K_p is the estimated static gain of said controlled process.

5. The control system of Claim 2, in which the delay time of said delay time process is substantially zero and the delay time of said feedforward process is larger than the delay time of said controlled process, and the control action of said feedforward control output is delayed by $\tau_{fc} = \tau_f - \tau_p$, wherein τ_{fc} is the delay time of said feedforward controller; τ_f is the delay time of said feedforward process; and τ_p is the delay time of said controlled process.

6. A multi-input-multi-output model-free adaptive quality variable control system, comprising:

a) a plurality of model-free adaptive controllers each having an error input and a control output;

b) a plurality of interrelated controlled processes each having a control input and a process output, and having a delay time process and a feedforward process associated therewith, the input of each said feedforward process being a disturbance, and

the output of said delay time processes being, respectively, the process variable of the associated process;

c) a plurality of feedforward controllers each having said disturbance as an input and having a feedforward controller output;

d) a plurality of delay predictors each having as its inputs the associated control output and the output of said delay time process associated therewith, and having as its output a dynamic feedback signal; and

e) a plurality of setpoint signals;

f) said error signals each being the difference between the associated setpoint signal and dynamic feedback signal;

g) said control input of each of said controlled processes being the sum of the associated control output and feedforward controller output; and

h) the input of each of said delay time processes being the sum of the associated process output and the output of the associated feedforward process; and

i) the output of each said delay time process being the delayed output of the associated process to be controlled.

7. The control system of Claim 6, in which each said feedforward controller has the Laplace transfer function of

$$G_{fc}(S) = \frac{K_{fc}e^{-\tau_{fc}S}}{T_{fc}S+1},$$

wherein $G_{fc}(S)$ is the Laplace transfer function of the feedforward controller; K_{fc} is the gain of the feedforward controller; T_{fc} is the feedforward time constant; τ_{fc} is the feedforward delay time; and S is the Laplace operator.

8. The control system of Claim 6, in which the delay times of said delay time processes are much larger than the delays inherent in said controlled processes and said feedforward processes, and the gain of each said feedforward controller is set at

$$K_{fc} = -\frac{K_f}{K_p},$$

wherein K_{fc} is the forward controller gain; K_f is the estimated static gain of the associated feedforward process; and K_p is the estimated static gain of the associated controlled process.

9. The control system of Claim 6, in which the delay times of said delay time processes are substantially zero and the delay times of said feedforward processes are larger than the delay times of said controlled processes, and the control action of each said feedforward control output is delayed by $\tau_{fc} = \tau_f - \tau_p$, wherein τ_{fc} is the delay time of said feedforward controller; τ_f is the delay time of the associated feedforward process; and τ_p is the delay time of the associated controlled process.

10. A model-free adaptive quality variable control system, comprising:

a) a model-free adaptive controller having an error input and a control output;

b) a controlled process having a control input and a process output, and having a delay time process and a feedforward process associated therewith, the input of said feedforward process being a disturbance, and the output of said delay time process being the process variable;

c) a feedforward controller having said disturbance as an input and having a feedforward controller output;

d) a signal emulator arranged, in response to the actual process variable, to emulate said process variable when said process variable is not measurable on line;

e) a delay predictor having as its inputs said control output and the output of said signal emulator, and having as its output a dynamic feedback signal; and

f) a setpoint signal;

g) said error signal being the difference value between said setpoint signal and said dynamic feedback signal;

h) said control input of said controlled process being the sum of said control output and said feedforward controller output; and

i) the input of said delay time process being the sum of said process output and the output of said feedforward process.

11. The control system of Claim 10, in which the Laplace transfer function of the input of said delay predictor is

$$Y_c(S) = Y_d(S) + Y_p(S)$$
$$= Y_d(S) + \frac{K(1-e^{-\tau S})}{TS+1}U(S),$$

wherein $Y_d(S)$, $Y_p(S)$, $U(S)$ and $Y_c(S)$ are the Laplace transforms of $y_d(t)$, $y_p(t)$, $u(t)$ and $y_c(t)$, respectively; $y_d(t)$ being the output of said signal emulator; $y_p(t)$ being the predictive signal; $y_c(t)$ being the output of said delay predictor; $u(t)$ being said control output; and K, T, and τ being the parameters of said delay predictor.

12. A multi-input-multi-output model-free adaptive quality variable control system, comprising:

a) a plurality of model-free adaptive controllers each having an error input and a control output;

b) a plurality of interrelated controlled processes each having a control input and a process output, and having a delay time process and a feedforward process associated therewith, the input of each said feedforward process being a disturbance, and the output of said delay time process being the process variable;

c) a plurality of feedforward controllers each having said disturbance as an input and having a feedforward controller output;

d) a plurality of signal emulators arranged, in response to the actual process variable of an associated process, to emulate said process variable when said process variable is not measurable on line;

e) a plurality of delay predictors each having as its inputs the associated control output and the output of said delay time process associated therewith, and having as its output a dynamic feedback signal; and

f) a plurality of setpoint signals;

g) said error signals each being the algebraic sum of the associated setpoint signal and dynamic feedback signal;

h) said control input of each of said controlled processes being the sum of the associated control output and feedforward controller output; and

i) the input of each of said delay time processes being the sum of the associated process output and the output of the associated feedforward process.

13. The control system of Claim 12, in which the Laplace transfer function of the input of each of said delay predictors is

$$\begin{aligned} Y_c(S) &= Y_d(S) + Y_p(S) \\ &= Y_d(S) + \frac{K(1-e^{-\tau S})}{TS+1} U(S), \end{aligned}$$

wherein $Y_d(S)$, $Y_p(S)$, $U(S)$ and $Y_c(S)$ are the Laplace transforms of $y_d(t)$, $y_p(t)$, $u(t)$ and $y_c(t)$, respectively; $y_d(t)$ being the output of said signal emulator; $y_p(t)$ being the predictive signal; $y_c(t)$ being the output of said delay predictor; $u(t)$ being said control output; and K, T, and τ being the parameters of said delay predictor.